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(19)


## (54) METHOD AND APPARATUS FOR TESTING THERMOCOUPLES


(71) We, THE SOLARTRON ELECTRONIC GROUP LIMITED, a British company, of Victoria Road, Farnborough, Hampshire, GU14 7PW, do

hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to methods and apparatus for testing thermocouples, particularly thermocouples which are associated with a data logger.

A typical data logger may have associated there with a large number of thermocouples, each disposed in a respective location in an installation such as an electricity generating plant or a chemical process plant being monitored by the data logger. Each thermocouple is selectively connectable to a measuring instrument, such as a digital voltmeter, which forms part of the data logger and which measures the respective thermal EMFs generated by the thermocouples to determine the respective temperatures at the various locations in which the thermocouples are disposed. From time to time, it is possible that one or more of the thermocouples may become damaged, e.g. during its removal to a different location in the installation. If the damage causes the thermocouple to become open-circuit, this can fairly readily be detected. However, it is possible that the damage can cause the thermocouple to exhibit a higher than normal resistance rather than simply becoming open-circuit. in this case the thermocouple may continue to produce an apparently normal output EMF, i.e. an output EMF within its normal operating range, which output EMF is nevertheless not correctly indicative of the temperature to which the thermocouple is being subjected. It is an object of the present invention to provide a method of, and apparatus for, testing thermocouples associated with a data logger, which method and apparatus substantially overcome this problem.

According to one aspect of the present invention, there is provided a method of testing a thermocouple associated with a data logger, comprising the steps of:

producing a first electrical output signal representative of the resistance of the thermocouple when the thermocouple is known to be operating correctly;

storing said first output signal; and

from time to time thereafter, producing a further electrical output signal representative of the resistance of the thermocouple and comparing said further output signal with the stored signal to check whether the resistance of the thermo-couple has changed.

In a preferred implementation of the invention, the step of producing a first output signal comprises the steps of:

producing a first electrical measurement signal representative of the magnitude of the output voltage produced by the thermocouple when the thermocouple is known to be operating correctly;

passing a known current through the thermocouple when the thermocouple is known to be operating correctly and producing a second electrical measurement signal representative of the magnitude of the output voltage produced by the thermo-couple while said current is passing therethrough; and

combining said first and second measurement signals so as to produce a difference signal representative of the difference between the respective magnitudes represented by said first and second measurement signals, the first output signal being constituted by said difference signal.

In this case, each step of producing a further output signal preferably comprises the steps of:

producing a third electrical measurement signal representative of the output voltage produced by the thermocouple;

passing said known current through the

thermocouple and producing a fourth electrical measurement signal representative of the magnitude of the output voltage produced by the thermocouple while said current is passing therethrough; and

combining said third and fourth measurement signals so as to produce a further difference signal representative of the difference between the respective magnitudes represented by said third and fourth measurement signals, the further output signal being constituted by the further difference signal.

Conveniently, the measurement signals are produced and combined digitally, whereby the first and further output signals are digital signals.

According to another aspect of the present invention, there is provided apparatus for use in a data logger for testing a thermocouple associated with the data logger, the apparatus comprising:

means for producing an electrical output signal representative of the resistance of the thermocouple;

signal storage means;

signal comparison means; and

control means operative to cause the output signal producing means to produce a first said output signal when the thermocouple is known to be operating correctly and to cause said first output signal to be stored in the storage means, the control means being operable from time to time thereafter to cause the output signal producing means to produce further output signals and to cause the comparison means to compare each further output signal with the signal stored in the storage means, to check whether the resistance of the thermocouple has changed.

Preferably, the output signal producing means comprises means for producing an electrical measurement signal representative of the magnitude of the output voltage produced by the thermocouple, means for passing a known current through the thermocouple, and a subtracting circuit, the control means being further operative to cause the output signal producing means to produce a first said measurement signal while said known current is not passing through the thermocouple, to cause the current passing means to pass said known current through the thermocouple and the output signal producing means to produce a second said measurement signal while said current is passing through the thermocouple, and to cause the substracting circuit to combine the first and the second measurement signals so as to produce a difference signal representative of the difference between the respective magnitudes represented by said first and said second measurement signals, the output signal being constituted by the difference signal.

Conveniently, the output signal producing means comprises an analogue-to-digital converter adapted to convert an anologue voltage applied thereto to a digital signal representative of the magnitude of the voltage.

The invention will now be described, by way of example, with reference to the accompanying drawing, which is a block circuit diagram of apparatus, in accordance with the present invention, for use in a data logger for testing thermocouples associated with the data logger.

The apparatus shown in the drawing is indicated generally at 10, and forms part of a data logger. The apparatus 10 comprises a pair of input terminals 11, 12 which are connected, in use, to receive the output voltage produced by a thermocouple 14 having a hot junction 16 and a cold junction 18. For simplicity, only a single thermocouple is shown, although in practice, in a typical data logger application there may be a plurality of thermocouples selectively connectable to the input terminals 11, 12 by means of a scanner unit.

The terminals 11, 12 are connected internally of the apparatus 10 to the input terminals 20, 21 of an analogue-to-digital converter 22, which has a control input 24 and an output 26. The converter 22 is adapted to produce at its output 26, upon receipt of a control signal at its control input 24, a digital output signal representative of the magnitude of the voltage applied to its inputs 20, 21.

The terminals 11, 12 are also connected, via respective switches 28, 30, to the outputs 32, 34 of a constant current source 36. The switches 28, 30 are typically reed relays.

The output 26 of the converter 22 is connected to a change-over switch 38, having a first position in which it connects the output 26 to the input 39 of a digital memory or store 40, e.g. a RAM, and a second position in which it connnects the output 26 to one input 42 of a digital substracting circuit 44. The store 40 has a control input 45, and an output 46 connected to another input 48 of the substracting circuit 44.

The subtracting circuit 44 has a control input 49, and an output 50 which is connected to a changeover switch 52. The switch 52 has a first position in which it connects the output 50 to the input 54 of a digital memory or store 56, e.g. another RAM, and a second position in which it

connects the output 50 to one comparison input 58 of a digital comparator 60. The store 56 has a control input 61, and an output 62 which is connected to another comparison input 64 of the comparator 60. The comparator 60 has a control input 65.

The comparator 60 also has an output 66, at which it is arranged to produce a logic level "1" signal when the respective digital signals applied to its inputs 58, 64 differ by more than a predetermined amount: when these digital signals do not differ by more than the predetermined amount, the comparator 60 produces at its output 66 a logic level "0" signal. The signal at the output 66 of the comparator 60 constitutes the output signal of the apparatus 10.

The apparatus 10 further comprises a sequence controller 70 having a set input 71, a start test input 72, and a plurality of control outputs 73, 74, 75, 76, 77: the control output 73 is connected to the control input 24 of the converter 22; the control output 74 is connected to the switches 28, 30, 38 (as indicated diagrammatically by arrows 78); the control output 75 is connected to the control inputs 45, 49 of the store 40 and the subtracting circuit 44 respectively; the control output 76 is connected to the switch 52 (as indicated diagrammatically by an arrow 79); and the control output 77 is connected to the control inputs 61, 65 of the store 56 and the comparator 60 respectively. The sequence controller 70 will not be described in detail, since it merely comprises a source of clock pulses, at least one counter, and a plurality of logic gating circuits and bistable circuits all arranged in a conventional manner to energise the control outputs 73—77 for predetermined amounts of time and in a predetermined sequence as will become apparent hereinafter.

In operation, and at a time when the thermocouple 14 is known to be operating correctly, and at a steady temperature, the thermocouple 14 is connected to the input terminals 11, 12 of the apparatus 10. In order to initiate the operation of the apparatus 10, a pulse is applied to the set input 71 of the sequence controller 70, and this pulse is operative, if necessary, to reset all of the switches 28, 30, 38, 52 to the positions illustrated in Figure 1. The output voltage $V_1$ produced by the thermocouple 14 which output voltage is the thermal EMF produced by the thermocouple, is thus applied to the input terminals 20, 21 of the converter 22.

A short time after this first pulse, the sequence controller 70 produces at its control output 73 a "digitise" control pulse, which is applied to the control input 24 of the converter 22, causing the converter to produce at its output 26 a first digital signal $V_{1D}$ representative of the magnitude of the voltage $V_1$. It will therefore be appreciated that the digital signal $V_{1D}$ is representative of the magnitude of the thermal EMF produced by the thermocouple 14. This first digital signal $V_{1D}$ is routed by the switch 38 into the store 40.

A short time after the digital signal $V_{1D}$ has been entered in the store 40, the sequence controller 70 produces at its control output 74 a signal which sets each of the switches 28, 30, 38 to their other (non-illustrated) positions. The constant current source 36 is therefore connected to, and passes a known current I through, the thermocouple 14. The thermocouple now produces an output voltage $V_2$, which represents the sum of its thermal EMF, $V_1$, and a voltage $V_3$ generated thereacross by passage of the known current I, the voltage $V_3$ being given by IR, where R is the resistance of the thermocouple 14 when it is operating correctly. Shortly thereafter, the sequence controller 70 produces at its output 73 a further "digitise" control pulse, which causes the converter 22 to produce at its output 26 a second digital signal $V_{D2}$ representative of the magnitude of the voltage $V_2$. This second digital signal is routed by the switch 38 to the input 42 of the substracting circuit 44. The time interval between the production of the first and second digital signals is typically less than a second, so the temperature of the thermocouple 14 may safely be regarded as constant.

The sequence controller 70 then produces at its output 75 a pulse which causes the digital signal in the store 40 to be read out and applied to the other input 48 of the substracting circuit 44, the same pulse also causing the subtracting circuit to substract algebraically one of the two digital signals at its inputs 42, 48 from the other. The subtracting circuit 44 thus produces at its output 50 a digital difference signal representative of the result of this subtraction, and therefore representative of the magnitude of the voltage $V_2-V_1=V_3=IR$: this digital difference signal is entered in the store 56 via the switch 52. Thus the store 56 now contains a digital signal representative of the magnitude of the resistance of the thermocouple 14 at a time when the thermocouple is known to be operating correctly.

In order subsequently to test the thermocouple 14, a pulse is applied to the start test input 72 of the sequence controller 70, which pulse sets the switch 52 to its non-illustrated position and resets the other switches 28, 30, 38 to their illustrated positions. Thereafter, the sequence of events described above for generating first

and second digital signals and for deriving a digital difference signal therefrom is repeated, but the digital difference signal is now applied via the switch 52 to the comparison input 58 of the comparator 60. The sequence controller 70 then produces at its output 77 a pulse which causes the digital signal in the store 56 to be non-destructively read out and applied to the other comparison input 64 of the comparator 60, the same pulse also causing the comparator to compare the digital signals at its inputs 58, 64. If the resistance of the thermocouple 14 has not changed significantly, indicating that the thermocouple is still operating correctly, the comparator 60 produces at its output 66 the aforementioned logic level "0" signal, while if the resistance of the thermocouple has changed significantly, the comparator 60 produces a logic level "1" signal at its output 66: this latter signal can be arranged to operate an alarm, e.g. a warning light, if desired.

The whole test procedure outlined above is repeated from time to time to maintain a continuous check on the thermocouple 14, and may be initiated manually and/or by a timing unit forming part of the data logger. It does not matter that the temperature of the thermocouple 14 may be different for each test, since the thermal EMF produced by the thermocouple, whatever its value, is cancelled by the subtraction operation.

In order to cater for a plurality of thermocouples, it is merely necessary to expand the capacity of the store 56 to hold a respective digital difference signal for each thermocouple, and to arrange the sequence controller firstly to repeat its entire sequence of operation in response to the first pulse applied to the input 71 for each thermocouple in turn, and secondly to repeat its entire sequence of operation in response to each start test pulse for each thermocouple in turn (while correctly addressing the store 56 for each thermocouple). Alternatively, the capacity of the store 40 can also be expanded, and the sequence controller 70 can be arranged to cause the sequential entry in the store 40 of a respective first digital signal derived from each thermocouple in turn, with the switches 28, 30 in their illustrated positions. The sequence controller 70 is then arranged to change the switches 28, 30 to their other positions, and to cause the converter 22 to produce a respective second digital signal for each thermocouple in turn, each second digital signal being subtractively combined in the subtracting circuit 44 with the appropriate first digital signal read from the store 40 to produce a respective digital difference signal. These digital difference signals are either entered in the store 56 or applied to the comparator 60, in dependence upon whether their production was originally initiated by a pulse at the input 71 or the input 72 of the sequence controller 70.

It will be appreciated that many modifications can be made to the described embodiment of the invention. In particular, in a computer-controlled data logger or a data logger controlled by a microprocessor with associated storage, a suitable current source such as the source 36 can be provided, and then the method according to the invention can be performed by suitably programming the computer or microprocessor to operate the data logger to perform the various measurements required in the correct sequence.

Also, although the switches 38 and 52 are shown as simple mechanical switches, it will be appreciated that in practice they are implemented as solid state semi-conductor switches.

WHAT WE CLAIM IS:—

1. A method of testing a thermocouple associated with a data logger, comprising the steps of:

producing a first electrical output signal representative of the resistance of the thermocouple when the thermocouple is known to be operating correctly;

storing said first output signal; and

from time to time thereafter, producing a further electrical output signal representative of the resistance of the thermocouple and comparing said further output signal with the stored signal to check whether the resistance of the thermocouple has changed.

2. A method as claimed in claim 1, wherein the step of producing a first output signal comprises the steps of:

producing a first electrical measurement signal representative of the magnitude of the output voltage produced by the thermocouple when the thermocouple is known to be operating correctly;

passing a known current through the thermocouple when the thermocouple is known to be operating correctly and producing a second electrical measurement signal representative of the magnitude of the output voltage produced by the thermocouple while said current is passing therethrough; and

combining said first and second measurement signals so as to produce a difference signal representative of the difference between the respective magnitudes represented by said first and second measurement signals, the first output signal being constituted by said difference signal.

3. A method as claimed in claim 2 wherein each step of producing a further output signal comprises the steps of:

producing a third electrical measurement signal representative of the output voltage produced by the thermocouple;

passing said known current through the thermocouple and producing a fourth electrical measurement signal representative of the magnitude of the output voltage produced by the thermocouple while said current is passing therethrough; and

combining said third and fourth measurement signals so as to produce a further difference signal representative of the difference between the respective magnitudes represented by said third and fourth measurement signals, the further output signal being constituted by the further difference signal.

4. A method as claimed in claim 2 or claim 3, wherein the measurement signals are produced and combined digitally, whereby the first and further output signals are digital signals.

5. Apparatus for use in a data logger for testing a thermocouple associated with the data logger, the apparatus comprising:

means for producing an electrical output signal representative of the resistance of the thermocouple;

signal storage means;

signal comparison means; and

control means operative to cause the output signal producing means to produce a first said output signal when the thermocouple is known to be operating correctly and to cause said first output signal to be stored in the storage means, the control means being operable from time to time thereafter to cause the output signal producing means to produce further output signals and to cause the comparison means to compare each further output signal with the signal stored in the storage means, to check whether the resistance of the thermocouple has changed.

6. Apparatus as claimed in claim 5, wherein the output signal producing means comprises means for producing an electrical measurement signal representative of the magnitude of the output voltage from the thermocouple, means for passing a known current through the thermocouple, and a substracting circuit, the control means being further operative to cause the output signal producing means to produce a first said measurement signal while said known current is not passing through the thermocouple, to cause the current passing means to pass said known current through the thermocouple and the output signal producing means to produce a second said measurement signal while said current is passing through the thermocouple, and to cause the subtracting circuit to combine the first and the second measurement signals so as to produce a difference signal representative of the difference between the respective magnitudes represented by said first and said second measurement signals, the output signal being constituted by the difference signal.

7. Apparatus as claimed in claim 6, wherein the output signal producing means further comprises an analogue-to-digital converter adapted to convert the analogue output voltage from the thermocouple to a digital signal representative of the magnitude of the voltage.

8. A method of testing a thermocouple associated with a data logger, the method being substantially as herein described.

9. Apparatus for use in a data logger for testing a thermocouple associated with the data logger, the apparatus being substantially as herein described with reference to the accompanying drawing.

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